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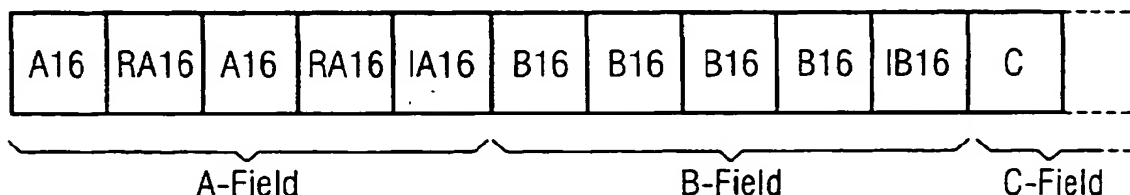
(54) **Synchronization preamble in an OFDM system**

(57) The invention is based on the synchronization and training preambles. The optimized sequence is very suitable to generate a preamble or a part (also called field) of it by mapping the sequence to the appropriate subcarriers of a OFDM symbol with a FFT size of 64. The benefit of the invention is the improved timing accuracy when the autocorrelation result in the B-FIELD is used for synchronization. The time domain structures of the preambles according to the prior art are not changed according to the invention. The advantages of

the present invention can be summarized as follows:
The invention proposes an OFDM based synchronization symbol with a low peak-to-average-power-ratio and a small dynamic range,

- the synchronization performance (timing accuracy compared to current preambles) is improved,
- the specified time domain preamble structures according to the prior art are not modified, and
- no extra complexity is needed.

FIG 1



EP 1 049 302 A1

Description

[0001] The present invention relates to a synchronization preamble structure for the synchronization of a receiver of a OFDM transmission. The invention furthermore relates to an OFDM transmitter as well as to a method for the synchronization of a receiver of an OFDM transmission system.

[0002] A synchronization preamble structure as shown in figure 1 is known. This known synchronization preamble structure can be subdivided in a A-FIELD, B-FIELD and a C-FIELD. The A-FIELD and the B-FIELD are subdivided in further parts. Each of the A-FIELD and the B-FIELD and the C-FIELD is designed to have an optimized special synchronization function at the receiving side. The A-FIELD for example serves for a coarse frame detection and an automatic gain control (AGC). The B-FIELD serves as a coarse frequency offset and timing synchronization. The C-FIELD serves for a channel estimation and fine synchronization.

[0003] Details about the concrete structure and generation of the B-FIELD can be found in the European patent application 99 103 379.6 in the name of Sony International (Europe) GmbH, which is to be regarded as representing prior art according to article 54(3) EPC. Regarding the details of the B-FIELD and generally the generation of the time domain synchronization preamble signal as shown in figure 1 reference is made to said prior non-prepublished application.

[0004] The symbols of the C-FIELD, which is generally of minor interest for the present invention, are defined in frequency domain as

$$C64_{-26...26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, 1, 0, \\ 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, 1, 1, 1, 1\}$$

[0005] The symbols B16 of the B-FIELD are short OFDM symbols, of which the subcarriers ± 4 , ± 8 , ± 12 , ± 16 , ± 20 , ± 24 are modulated. The content in the frequency domain is equal to the one proposed in the above-cited EP-99 103 379.6. It can be defined as

$$B16_{-26...26} = \sqrt{2} \cdot \{0, 0, 1 + j, 0, 0, 0, -1 + j, 0, 0, 0, -1 - j, 0, 0, 0, 1 - j, 0, 0, 0, 1 - \\ j, 0, 0, 0, 0, 0, 0, 1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 - j, 0, 0, 0, -1 + j, 0, 0, 0, 1 + j, 0, 0\}$$

[0006] The last repetition of the B-FIELD and the time domain, which is called IB16, is a sign inverted copy of the preceding B16. Note that the symbol sequence mapped onto subcarriers to generate B16 has particularly advantages for a low PAPR (peak-to-average-power-ratio) and small dynamic range.

[0007] According to the known concept as shown in figure 1 the symbols A16 of the A-FIELD are short OFDM symbols, of which the subcarriers ± 2 , ± 6 , ± 10 , ± 14 , ± 18 , ± 22 are modulated (for a 64 point IDFT or IFFT). The content in the frequency domain can be defined as

$$A16_{-26...26} = \sqrt{2} \cdot \{0, 0, 0, 0, +1 + j, 0, 0, 0, -1 + j, 0, 0, 0, -1 - j, 0, 0, 0, +1 - \\ j, 0, 0, 0, +1 + j, 0, 0, 0, +1 - j, 0, 0, 0, +1 + j, 0, 0, 0, +1 - j, 0, 0, 0, +1 - \\ j, 0, 0, 0, -1 - j, 0, 0, 0, -1 + j, 0, 0, 0, 0\}$$

[0008] The sign reversal of every second A16 symbol in the time domain is automatically achieved by the specified subcarrier loading. The last repetition of the A-FIELD in time domain, which is called IA16, is a copy of the preceding RA16.

[0009] It is the object of the present invention to provide for a technique departing from the above-shown proposal which allows for better autocorrelation properties on a receiving side of a OFDM system.

[0010] This object is achieved by means of the features of the independent claims. The dependent claims develop further the central idea of the present invention.

[0011] According to the present invention therefore a synchronization preamble structure for the synchronization of a receiver of a OFDM transmission is proposed. The synchronization structure thereby comprises at least one first and one second part. At least one first part thereby is designed for a coarse frame detection and/or an AGC control. At least one second part following the at least one first part in the time domain is designed for a timing and frequency

synchronization. The at least one first part and the at least one second part contain Inverse Fast Fourier transformed frequency domain sequences of complex symbols.

[0012] The sequence of the at least one first part is set depending on the sequence of the at least one second part of the synchronization preamble structure such that the synchronization performance is optimized. Therefore, according to the present invention for the first time it has been seen that by changing the sequence of the first part of the synchronization preamble structure can effect in a positive way the second part of the synchronization preamble structure. With other words, the present invention shows that for example the quality of the autocorrelation peak generated mainly by the sequence of the at least one second part of the synchronization preamble structure can be improved by optimizing this sequence of the at least one first part of the synchronization preamble structure.

[0013] The design principle is to set the frequency domain content of the A-FIELD such that the resulting time domain waveform (with respect to the B-FIELD time domain waveform) results in improved synchronization properties. Note that different synchronization techniques such as auto-correlation or cross-correlation can be used on the receiver side.

[0014] The frequency domain sequence of the at least one first part can be set depending on the frequency domain sequence of the at least one second part such that a second correlation peak mainly generated by the at least one second part is optimized. The expression „mainly generated“ has been used to take into account that the sequence of the at least one first part of the synchronization preamble structure has some influence on the second correlation peak.

[0015] The time domain signal of the synchronization preamble can be generated by mapping frequency domain sequences of 12 complex symbols to a 64 point Inverse Fast Fourier Transformation (IFFT). Thereby the remaining inputs of the IFFT are set to 0. The last six complex symbols of the sequence of the at least one first part thereby can be identical with the last six complex symbols of the sequence of the at least one second part.

[0016] Additionally or alternatively, the first six complex symbols of the sequence of the at least one first part of the synchronization preamble structure can be respectively different to the first six complex symbols of the sequence of the at least one second part of the synchronization preamble structure.

[0017] The frequency domain sequence of the at least one first part can be

$$S_A = (1-i), (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i),$$

[0018] In this case the frequency domain sequence of the at least one second part is

$$S_B = (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i).$$

[0019] According to the present invention furthermore an OFDM transmitter designed for the transmission of a synchronization preamble as set forth above in the BCCH channel of a OFDM system is provided.

[0020] As a further aspect of the present invention a method for the synchronization of a receiver of a OFDM transmission system is provided. Thereby the synchronization structure comprises at least two parts. At least one first part is thereby designed for a coarse frame detection and/or an AGC control. At least one second part following the at least one first part in the time domain is designed for a timing and frequency synchronization. The at least one first part and the at least one second part contain Inverse Fast Fourier (IFFT) transformed frequency domain sequences of complex symbols.

[0021] The sequence of the at least one first part of the synchronization preamble structure therefore is such that the synchronization performance is optimized depending on the sequence of the at least one second part.

[0022] In the following preferred embodiments of the present invention will be explained with reference to the enclosed figures of the drawing such that further objects, advantages and features of the present invention will come clearer.

Figure 1 shows the structure of a synchronization preamble structure,

Figure 2 shows an autocorrelation dock diagram,

Figure 3 shows an ideal autocorrelation result when using the A-FIELD sequence according to the prior art,

Figure 4 shows the ideal autocorrelation result when using the A-FIELD sequence according to the present invention,

Figure 5 shows the time domain signal (In and Quad part) of the A-FIELD sequence according to the prior art in

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[0035] The A-FIELD sequence according to the prior art is:

$$S1..12 = (1+j), (-1+j), (-1-j), (1-j), (1+j), (1-j), (1+j), (1-j), (1+j), (1-j), (-1-j), (-1+j)$$

[0036] One example for an A-FIELD sequence according to the present invention is:

$$S1..12 = (1-j), (1+j), (-1+j), (-1-j), (1-j), (-1-j), (1-j), (-1-j), (1-j), (-1-j), (-1+j), (1+j)$$

[0037] Thereby the full sequence for the field B is:

$$S_{-26,26} =$$

$$\text{sqrt}(2) \cdot \{0,0,S1,0,0,0,S2,0,0,0,S3,0,0,0,S4,0,0,0,S5,0,0,0,S6,0,0,0,0,0,0,S7,0,0,0, \\ S8,0,0,0,S9,0,0,0,S10,0,0,0,S11,0,0,0,S12,0,0\}$$

[0038] Thereby $\sqrt{2}$ is used to normalize the power. Applying a 64-point IFFT to the vector S, wherein the remaining 15 values are set to 0, four short training symbols can be generated. The IFFT output is cyclically extended to result in the dedicated number of short symbols.

[0039] The sequence for the field B thereby is:

$$S1..12 = (1+j), (-1+j), (-1-j), (1-j), (-1-j), (1-j), (1-j), (-1-j), (1-j), (-1-j), (-1+j), (1+j)$$

[0040] With reference to figure 2 now an autocorrelation technique on the receiving side of an OFDM system will be explained. The received signal is delayed by a delaying unit 2 by the correlation delay D_{ac} . The conjugate complex samples of the delayed version of the signals are generated 3 and multiplied 4 with the received samples. The products are set into the moving average unit 6 with a window size W_{ac} and are then postprocessed for a threshold detection and/or maximum search (units 5, 7, 8) to find the correct timing. The complex correlation result at the peak position generated by the unit 9 can be used to estimate the frequency offset.

[0041] With reference to figure 3 to 7 now simulation results will be explained to show the performance of the proposed technique. Figure 3 thereby shows the ideal autocorrelation result (amplitude and phase) of a BCCH preamble according to the prior art. The autocorrelation result is used to identify a frame start, adjust the AGC and to effect timing and frequency synchronization. Particularly the B-FIELD can be used for the later synchronization tasks (timing and frequency synchronization). It is very important to achieve timing synchronization as exactly as possible as can be seen from figure 3 according to the prior art the BCCH structure presents a plateau which can be identified before the autocorrelation amplitude peak in field B. This "plateau" effect decreases the timing accuracy significantly. Apart from the plateau the peak itself does not present a good and well-shaped quality.

[0042] Figure 4 shows the autocorrelation performance of the BCCH preamble according to the present invention. The above described plateau and side lobe effect encountered by using the prior art proposal, can be avoided if the A-FIELD sequence according to the present invention is used. An optimized matching between A- and B-FIELD of the BCCH preamble is achieved and thus the timing accuracy can be improved, which is basically achieved through the specified time domain structure. In Figure 4 two clear single autocorrelation amplitude peaks can be identified in the BCCH preamble, if the sequence according to the prior art is used for the generation of the A-FIELD.

[0043] In the following the time domain signal properties will be explained with reference to figures 5 to 7.

[0044] For OFDM (or in general multicarrier signals) the signal envelope fluctuation (called peak-to-average-power-ratio = PAPR) is of great concern. A large PAPR results in poor transmission (due to non linear distortion effects of the power amplifier) and signal limiting components in the transmission system (e.g. limited dynamic range of the A/B converter).

[0045] For synchronization sequences it is even more desirable to have signals with the low PAPR and low dynamic range in order to accelerate the receiver AGC (automatic gain control) locking and adjusting the reference signal value for the A/B converter (the whole dynamic range of the incoming signal should be covered by the A/B converter resolution without any overflow/underflow).

[0046] Figure 6 shows the time domain power envelope of the resulting time domain signal wave form when using the A-FIELD sequence according to the prior art, in dB. 8-times oversampling was considered in order to ensure that the peaks were captured correctly using the limited 64-point IFFT. The resulting PAPR is 2.13 dB and the dynamic

range is 6.13 dB (with 8-times oversampling).

[0047] Figure 5 shows the real and imaginary part of the resulting transmitted time domain wave form.

[0048] Figure 8 shows the time domain power envelope of the resulting time domain signal wave form when using the proposed sequence according to the present invention. 8-times oversampling was considered in order to ensure that the peaks were captured correctly using the limited 64-point IFFT. The resulting PAPR is 2.13 dB and the dynamic range is 6.13 dB. The PAPR and the dynamic range therefore are not degraded when using the sequences according to the present invention in comparison to the prior art.

[0049] Figure 7 shows a real and imaginary part of the resulting transmitted time domain wave form.

[0050] The invention proposes a technique for an optimized synchronization (synch) symbol sequence to be used in OFDM transmission systems. The synchronization symbol structure is constructed using specially designed OFDM symbols with an optimized sequence, which is mapped onto the modulated subcarriers. The resulting synchronization symbols consists of several repetitions in the time domain. Using the proposed sequence the resulting synchronization symbol provides a high-timing detection and frequency detection of said estimation accuracy. Furthermore, the burst is optimized to achieve a very low envelope fluctuation and a very low dynamic range to reduce complexity on the receiver and to increase the frequency and time detection performance. The proposed A-FIELD sequence is particularly optimized with respect to all other synchronization symbols.

[0051] The invention is based on the synchronization and training preambles. The optimized sequence is very suitable to generate a preamble or a part (also called field) of it by mapping the sequence to the appropriate subcarriers of a OFDM symbol with a IFFT size of 64. The benefit of the invention is the improved timing accuracy when the autocorrelation result in the B-FIELD is used for synchronization. The time domain structures of the preambles according to the prior art are not changed according to the invention.

[0052] The advantages of the present invention can be summarized as follows:

- The invention proposes an OFDM based synchronization symbol with a low peak-to-average-power-ratio and small dynamic range,
- the synchronization performance (timing accuracy compared to current preambles) is improved,
- the specified time domain preamble structures according to the prior art are not modified, and
- no extra complexity is needed.

Claims

1. Synchronization preamble structure for the synchronization of a receiver of a OFDM transmission system, wherein

- the synchronization structure comprises at least one first part (A-FIELD) and at least one second part (B-FIELD),
- at least one first part (A-FIELD) being designed for a coarse frame detection and/or a AGC control, and
- at least one second part (B-FIELD) following the at least one first part in the time domain,
- the at least one second part (B-FIELD) being designed for a timing and frequency synchronization,
- the at least one first part (A-FIELD) and the at least one second part (B-FIELD) containing Inverse Fast Fourier (IFFT) transformed frequency domain sequences of complex symbols,

characterized in that

the frequency domain sequence of the at least one first part (A-FIELD) is set depending on the sequence of the at least one second part (B-FIELD) of the synchronization preamble structure such that the synchronization performance of the resulting time domain waveform is optimized.

2. Synchronization preamble structure according to claim 1, characterized in that

the frequency domain sequence of the at least one first part (A-FIELD) is set depending on the frequency domain sequence of the at least one second part (B-FIELD) such that a second autocorrelation peak mainly generated by the at least one second part (B-FIELD) of the synchronization preamble structure is optimized.

3. Synchronization preamble structure according to claim 2, characterized in that

the time domain signal of the synchronization preamble is generated by mapping frequency domain sequences of 12 complex symbols to a 64 point IFFT, wherein the remaining inputs of the IFFT are set to zero,

the last six complex symbols of the sequence of the at least one first part being identical with the last six complex symbols of the sequence of the at least one second part.

4. Synchronization preamble structure according to claim 2 or 3,
characterized in that

the time domain signal of the synchronization preamble is generated by mapping frequency domain sequences of 12 complex symbols to a 64 point IFFT,
wherein the remaining inputs of the IFFT are set to zero,
the first six complex symbols of the sequence of the at least one first part being respectively different to the first six complex symbols of the sequence of the at least second part.

5. Synchronization preamble structure according to anyone of claims 2 to 4,
characterized in that
the frequency domain sequence of the at least one first part (A-FIELD) is

$$S_A = (1-i), (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i),$$

and the frequency domain sequence of the at least one second part (B-FIELD) is

$$S_B = (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i).$$

6. OFDM transmitter,
designed for transmitting a synchronization preamble according to anyone of the preceding claims in the BCCH channel of an OFDM system.

7. Method for the synchronization of a receiver of a OFDM transmission,
wherein

- the synchronization structure comprises at least one first part (A-FIELD) and at least one second part (B-FIELD),
- at least one first part (A-FIELD) being designed for a coarse frame detection and/or a AGC control, and
- at least one second part (B-FIELD) following the at least one first part in the time domain,
- the at least one second part (B-FIELD) being designed for a timing and frequency synchronization,
- the at least one first part (A-FIELD) and the at least one second part (B-FIELD) containing Inverse Fast Fourier (IFFT) transformed frequency domain sequences of complex symbols,

characterized by

the step of setting the frequency domain sequence of the at least one first part (A-FIELD) depending on the sequence of the at least one second part (B-FIELD) of the synchronization preamble structure such that the synchronization performance of the resulting time domain waveform is optimized.

8. Method according to claim 7,
characterized in that

the frequency domain sequence of the at least one first part (A-FIELD) is set depending on the frequency domain sequence of the at least one second part (B-FIELD) of the synchronization preamble structure such that a second autocorrelation peak mainly generated by the at least one second part (B-FIELD) is optimized.

9. Method according to claim 8,
characterized in that

the time domain signal of the synchronization preamble is generated by mapping frequency domain sequences of 12 complex symbols to a 64 point IFFT,
wherein the remaining inputs of the IFFT are set to zero,
the last six complex symbols of the sequence of the at least one first part being identical with the last six complex symbols of the sequence of the at least one second part.

10. Method according to claim 8 or 9,
characterized in that

the time domain signal of the synchronization preamble is generated by mapping frequency domain sequences
of 12 complex symbols to a 64 point IFFT,
wherein the remaining inputs of the IFFT are set to zero,
the first complex symbols of the sequence of the at least one first part being respectively different to the first
six complex symbols of the sequence of the at least one second part.

11. Method according to anyone of claims 8 to 10,
characterized in that
the frequency domain sequence of the at least one first part is

$$S_A = (1-i), (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i),$$

and the frequency domain sequence of the at least one second part is

$$S_B = (1+i), (-1+i), (-1-i), (1-i), (-1-i), (1-i), (1-i), (-1-i), (1-i), (-1-i), (-1+i), (1+i).$$

FIG 1

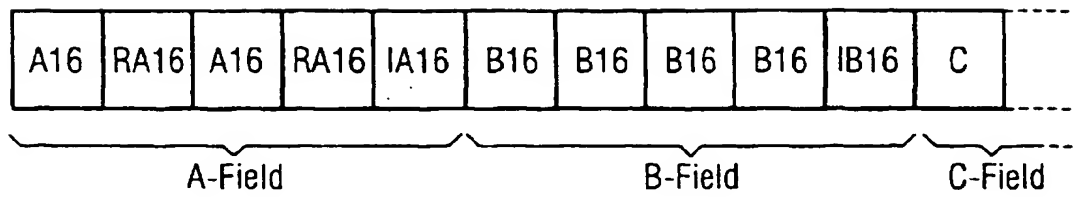


FIG 2

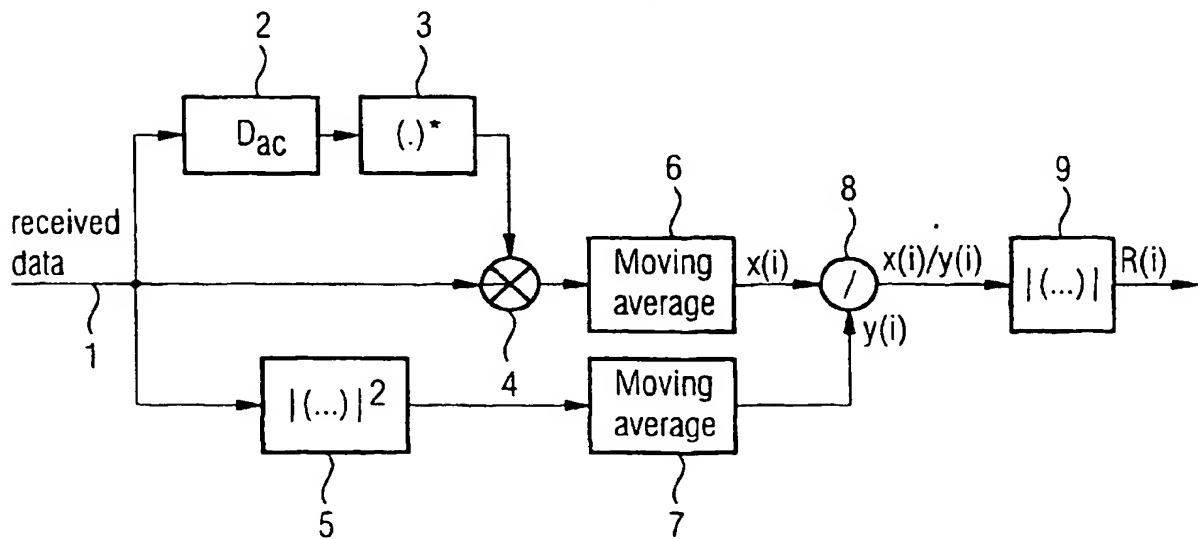


FIG 3

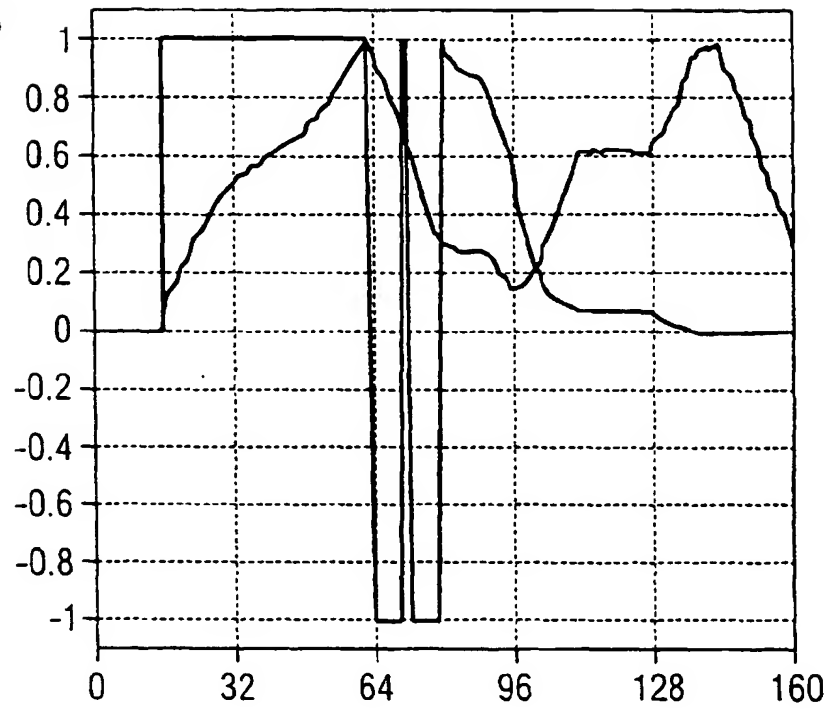


FIG 4

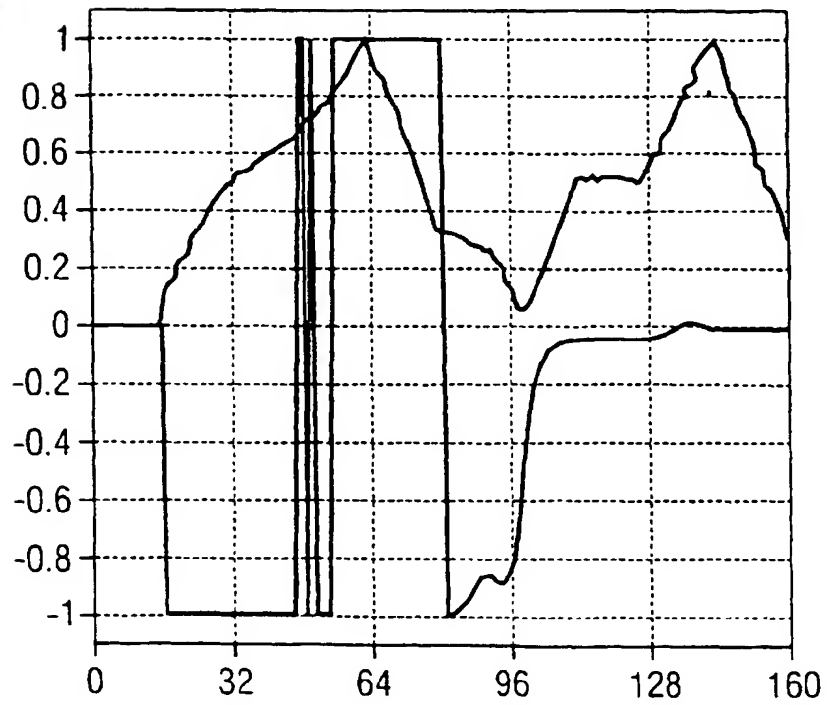


FIG 5

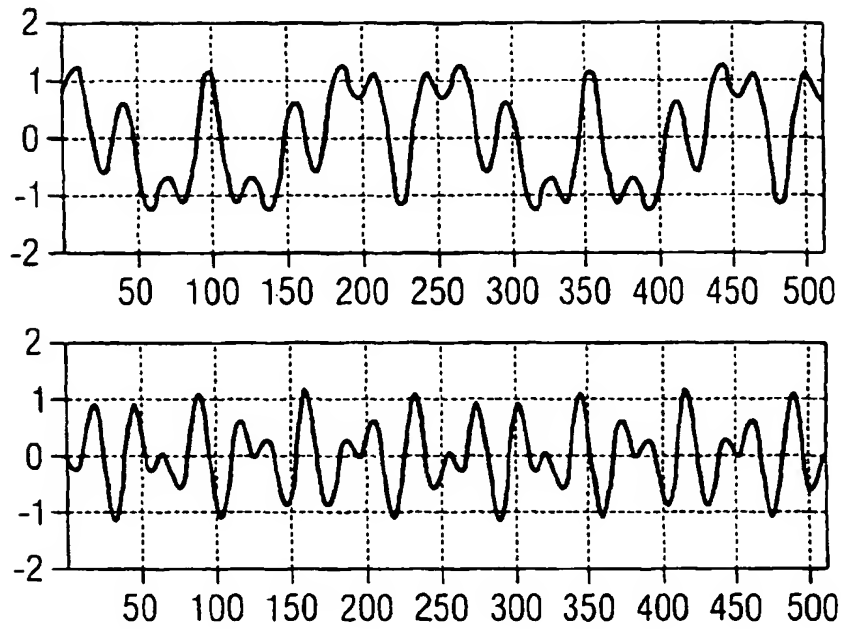


FIG 6

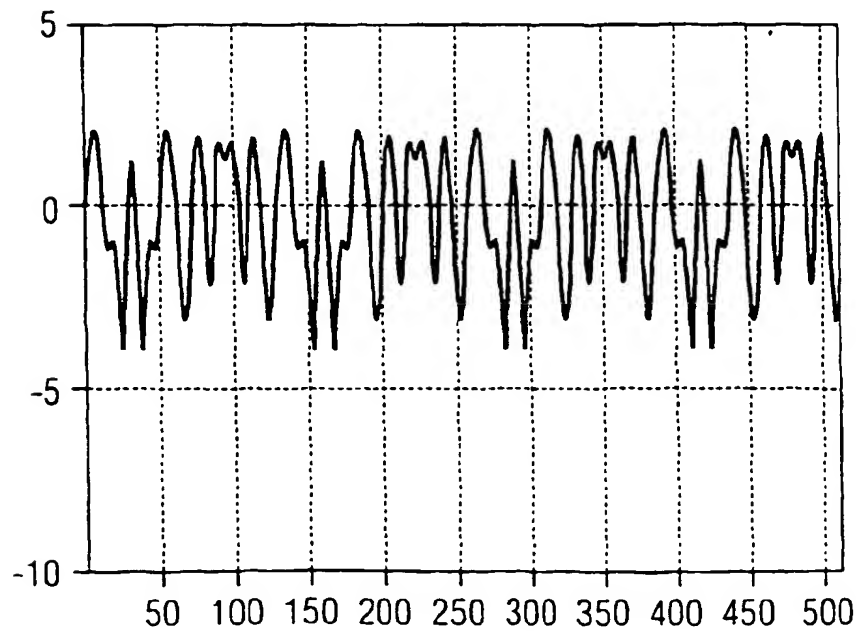


FIG 7

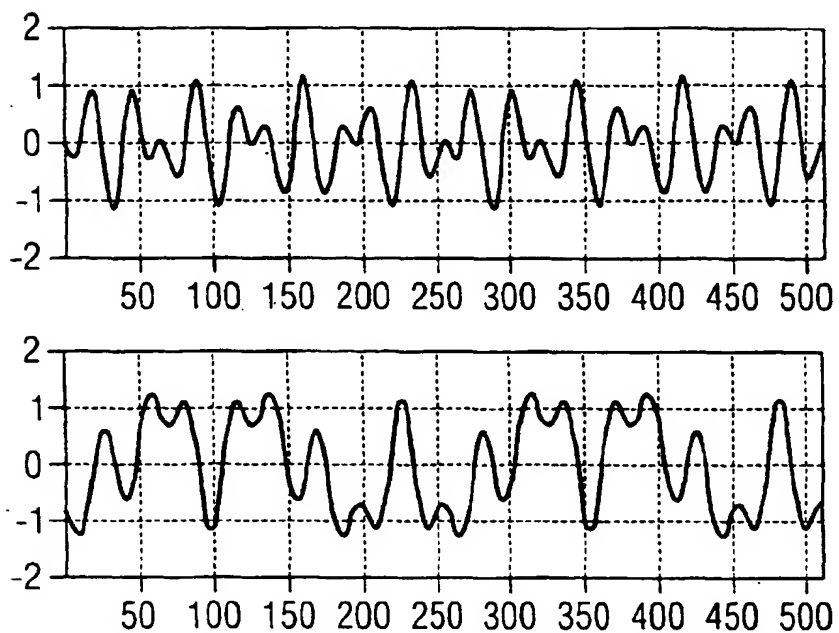
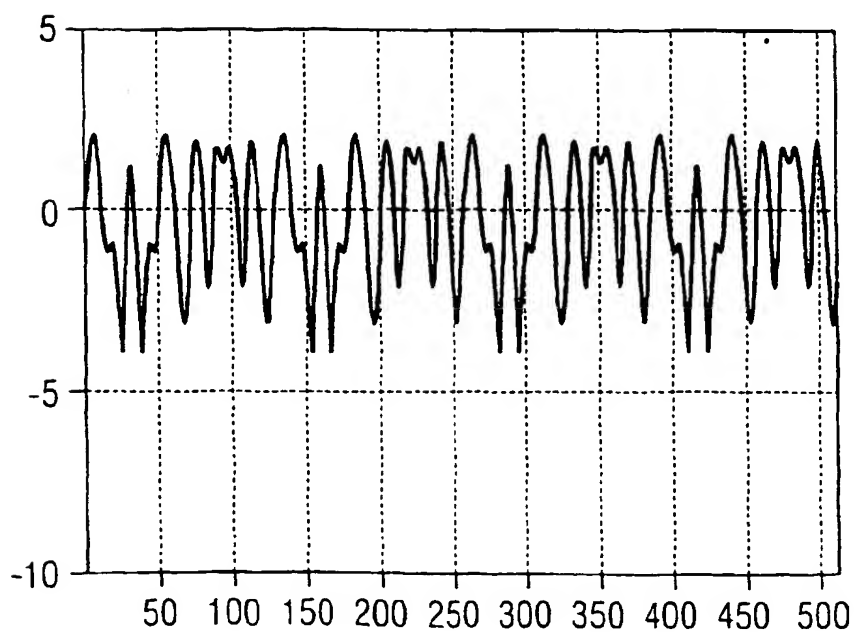


FIG 8





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EUROPEAN SEARCH REPORT

Application Number
EP 99 10 8083

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	SCHMIDL T M ET AL: "LOW-OVERHEAD, LOW-COMPLEXITY BURST SYNCHRONIZATION FOR OFDM" 1996 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS (ICC), CONVERGING TECHNOLOGIES FOR TOMORROW'S APPLICATIONS DALLAS, 1996, vol. 3, 23 June 1996 (1996-06-23), pages 1301-1306, XP000625022 IEEE, New York, USA ISBN: 0-7803-3251-2	1,2,6-8	H04L27/26
A	* abstract * * page 1301, left-hand column, paragraph 3 * * section 3.1 * * table 1 *	3-5,9-11	
A	KELLER T ET AL: "ORTHOGONAL FREQUENCY DIVISION MULTIPLEX SYNCHRONISATION TECHNIQUES FOR WIRELESS LOCAL AREA NETWORKS" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, vol. 3, 15 October 1996 (1996-10-15), pages 963-967, XP002063294 IEEE, New York, USA * section 2 * * figures 1,2 *	1-11	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04L H04M
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 27 September 1999	Examiner Langinieux, F
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EUROPEAN SEARCH REPORT

Application Number
EP 99 10 8083

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	<p>FETCHEL S A ET AL: "Fast Frame Synchronization, Frequency Offset Estimation and Channel Acquisition for Spontaneous Transmission Over Unknown Frequency-Selective Radio Channels" PROCEEDINGS OF THE 1993 IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, PIMRC'93,1993, pages 229-233, XP002116291 Piscataway, NJ, USA</p> <p>* figure 1 *</p> <p>* section 4 *</p> <p>* abstract *</p>	1,2,7,8	
E	<p>EP 0 915 597 A (SONY INTERNATIONAL EUROP GMBH) 12 May 1999 (1999-05-12)</p> <p>* abstract *</p> <p>* paragraphs '0018!-'0027! *</p> <p>* paragraphs '0035!-'0037! *</p> <p>* figures 1,2 *</p>	1,6,7	
The present search report has been drawn up for all claims			<p>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</p>
Place of search		Date of completion of the search	Examiner
THE HAGUE		27 September 1999	Langinieux, F
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone</p> <p>Y : particularly relevant if combined with another document of the same category</p> <p>A : technological background</p> <p>O : non-written disclosure</p> <p>P : intermediate document</p> <p>T : theory or principle underlying the invention</p> <p>E : earlier patent document, but published on, or after the filing date</p> <p>D : document cited in the application</p> <p>L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 99 10 8083

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27-09-1999

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